Thesis/
Reports
Weigmann
D.L.

SURVEY OF SACRAMENTO MOUNTAIN SALAMANDER HABITAT OF THE CLOUDCROFT AND MAYHILL DISTRICTS OF THE LINCOLN NATIONAL FOREST

by

D.L. Weigmann, et al.

FINAL REPORT

SURVEY OF SACRAMENTO MOUNTAIN SALAMANDER HABITAT OF THE CLOUDCROFT AND MAYHILL DISTRICTS OF THE LINCOLN NATIONAL FOREST

by

Diana L. Weigmann, Principal Investigator

Mark Hakkila

Karl Whitmore

and

Richard A. Cole

New Mexico State University

Las Cruces, New Mexico

Contract and Order Number: OM-40-7512-0-632

U.S.D.A. Lincoln National Forest

Alamogordo, New Mexico

19 December 1980

LIBRARY COPY
ROCKY MT. FOREST & RANGE
EXPERIMENT STATION

INTRODUCTION

The major emphasis of this research was to determine and describe the important habitat factors that are associated with the Sacramento Mountain salamander (Aneides hardii). Prior to this research, little quantitative information was available on the ecology and natural history of this species. The Lincoln National Forest contains much of the known habitat of this salamander, a terrestrial, woodland plethodontid restricted to the higher elevations of the Sacramento, Capitan and White Mountains (Wake, 1965). Aneides hardii has been classified as an endangered species (Group II) by the state of New Mexico, mainly because of its restricted distribution.

In earlier studies, certain aspects of the natural history and ecology (Lowe, 1950; Johnston and Schad, 1959 and Wake, 1965) and physiology (Whitford, 1968) were examined. Most specimens previously had been collected in spruce-fir vegetation at elevations of 8500 to 9600 feet. More specifically, the overstory vegetation under which salamanders had typically been found was pure stands of Engleman spruce (Picea engelmannii) or mixed stands of spruce, Douglas fir (Pseudotsuga menziesii) and white fir (Abies spp.) with small oaks (Quercus spp.) present among the dominant conifers.

Salamanders were typically associated with downed Douglas fir logs and a few individuals were collected from spruce logs or cracks in various deadwood. The logs that the salamanders appear to prefer are in

advanced stages of decomposition, actually saturated with water and punky.

Although little information is available on the winter movements and hibernation of this species, it has been suggested that they move mainly to subterranean cavities or to other similar sites away from freezing temperatures.

Longevity and growth rates of Aneides hardii are presently unknown. It has been suggested that they live for at least two years, since individuals have been maintained in the lab for 13 to 14 months. Information on captive salamanders indicates that individuals can grow 8 mm in one month or make the transition from juvenile to adult (37 mm to 45 mm snout-vent length) in this time period. The sex ratio appears to be equal for this species, although there are differences within particular sampling sites (fewer females than males). In all previous collections the adults outnumbered the juveniles, with adult to juvenile ratios of 2:1 or 1.25 to 1. Whether this is characteristic for the species or simply a collecting artifact because of salamander activity patterns, probability of observation by the collector or other factors is not known.

Data based on stomach contents suggest that salamanders feed randomly on food items of the appropriate sizes with ants and beetles being commonly consumed. In earlier studies, salamanders were never observed to be diurnally active in their natural habitats. However, captive salamanders initially foraged during daylight, but after acclimation to laboratory conditions were active at night or under low light regimes.

The actual times when egg clusters are deposited by the Sacramento Mountain salamander seemingly are related to the timing of the summer rains. Apparently courtship occurs in June, while oviposition and hatching may occur during the period from late July to September. Among all the plethodontid salamanders studied, Aneides hardii averaged the lowest number of eggs per clutch (about 4 eggs per clutch).

The critical thermal maximum for this species appears to be about 33.25°C (±0.07). This temperature is lower than for other Aneides species that have been examined (Rosenthal, 1957). Oxygen consumption used as an indicator of metabolic activity appears to be directly related to temperature changes. There are particularly large increases in oxygen consumption between 20-25°C. Optimum temperatures for activity appear to be between 15-20°C and Aneides hardii seems to be relatively resistant to dessication. The Sacramento Mountain salamander is more resistant to dessication than other species of Aneides that have been tested similarly (Ray, 1958). The temperatures of logs, where salamanders were found, averaged 12.5 to 13°C. Whitford (1968) suggests that temperatures around 15°C represents the environmental optimum for this species and this low critical thermal maximum reflects their genetic adaptations to the normal temperatures of their high elevation environment.

This study was designed to quantify the habitat characteristics of Aneides hardii, the Sacramento Mountain salamander. Among the variables measured were percent vegetal cover - overstory, midstory and ground story, elevation, aspect, percent slope, position on slope, D. B. H. (diameter of trees at breast height), soil moisture and pH. Dominant taxa comprising

the overstory, midstory and ground story were described. Actual salamander locality data was compared with adjusted transect information (weighted for salamander numbers) to discern the accuracy of the transect data in depicting salamander habitat. Additional information on dominant types of cover (logs, rocks, sticks, bark, stumps) and the average distances between these objects on transects with and without salamanders was assessed. Relevant quantitative data was procured on juvenile and adult salamander density in different types of habitats, distributional information on the prevalence of clumping of individuals and particular types of objects salamanders are likely to be associated with. The results of this study will provide substantial quantitative information on the ecology and natural history of Aneides hardii.

METHODS

Diurnal sampling was conducted primarily on slopes of northeast aspects at elevations above 8500 ft. A set of three transects, located on contours near the top, middle and bottom was sampled on gentle slopes (less than 10^{o}), moderate slopes (from 10^{o} to 30^{o}) and steep slopes (over 30^{o}). Appropriate locations for transects were selected by partitioning the total number of sections above 8500 ft on 7.5 minute topographic maps of the Lincoln National Forest. For the Alamogordo quadrangle, only a 15 minute topographic map was available. Actual transect sites were chosen randomly and equaled about one-half of the number of

sections over 8500 ft. By this method, 68 transect sites were selected. To assure that all sections were sampled similarly, alternate sets of transects were examined for each locality. The time allotted for field work was inadequate to complete all 68 transect sets; a total of 42 were analyzed.

For each transect, information on elevation, aspect, slope, D. B. H., % of vegetal cover - overstory (>3m), midstory (1-3 m) and ground story (<1 m) and dominant types of ground debris were recorded. Canopy cover was estimated with a spherical densiometer, aspect with a compass, slope with a clinometer and elevation from topographic maps. Soil samples were collected and subsequently analyzed for pH and soil moisture. Taxa comprising the ground story, midstory and overstory were described and general comments on the weather were made. Measurements of the density and major taxa of ground vegetation were influenced by the particular time the transect was sampled during the summer growing season. Transects were about one meter in width and length was determined by the distance necessary to search inside and under 100 objects that could potentially harbor salamanders. Transects were completed prematurely if 5 or more salamanders were located before 100 objects were searched. Ground debris had to be about 20 mm long and 7 mm wide, large enough to cover a juvenile salamander, to be counted as an appropriate object. Ground debris that met the criterion was turned or in the case of logs and stumps, stripped of bark and the interiors examined for salamanders. If logs were found diagonally or perpendicularly across the transect, they were searched only in a one meter section directly aligned with the transect along the contour. Logs lying lengthwise were counted as

more than one object in one meter sections.

Efforts were made to minimize habitat destruction, the remains of logs and rocks and sticks were returned to their original positions. A compass was used to delimit transect boundaries. If magnetic bearings of 90^{o} East or 0^{o} North resulted before 100 objects were searched, the direction of the transect was reversed and sampling continued a few meters uphill.

When salamanders were located along a transect, additional information was recorded on elevation, slope, D. B. H., aspect and overstory, midstory and ground story cover. Dominant overstory, midstory and ground story taxa and the major types of ground objects and distance between them were described at each salamander site. The object the salamander was associated with was noted and the length (mm) of the salamander was taken before returning it to its refugia.

Data on the different habitat variables were analyzed by a One-Way Analysis of Variance to confirm their importance in relation to the distribution of salamanders. The average distance between objects and the length of the transect on which specific numbers of salamanders were collected were used to estimate the population density of salamanders in the different types of habitats sampled. Additionally, information on salamander distribution was assessed to ascertain if they were typically dispersed, aggregated or occurred randomly.

Nocturnal transects were originally 100 meters long and were located in seven of eight vegetation types listed below. The seventh category was excluded because of the difficulty in locating these areas in Lincoln National Forest.

Nocturnal Transect Habitat Types

Category	Vegetation Type	Elevation	% Canopy	Aspect (magnetic)
1	Mixed conifer	>8500'	65-100	South to West
2	Mixed conifer	>8500'	65-100	North to East
3	Mixed conifer	>8500'	33-56*	South to West
4	Mixed conifer	>8500'	33-56*	North to East
5	Mixed conifer	>8500'	0-33*	South to West
6	Mixed conifer	>8500'	0-33*	North to East
7	Ponderosa pine	>8500'	66-100	South to West
8	Mixed conifer	>8500'	66-100	North to East

* In past timber cuts, if possible

Nocturnal transect locations were necessarily biased to allow several transects to be monitored in one night. Theoretically, this would have provided similar conditions among transects located in the different types of habitats, but precipitation in the study area was scattered and locally heavy. This resulted in extreme variations in ground moisture conditions.

Sampling was conducted by pacing 100 m along a previously marked route, searching a strip one meter wide with 6 volt hand-held flashlights and 6 volt miner's lights. From 24 transects of this type, one salamander was found. To determine whether the low success at finding salamanders was due to their inactivity or inadequate lighting, areas of known

high salamander density were searched on six different nights. No salamanders were located during this period, so a 24 volt lantern was employed for sampling on an additional five nights. Again, no salamanders were found to be active on the ground surface. To determine whether salamanders were actually inactive or simply difficult to observe, five salamanders were collected diurnally and released nocturnally on an area of approximately nine square meters. A search of this area for one minute demonstrated that the cryptic coloration of the salamanders was the limiting factor. A full five minutes was required to locate four of the five salamanders, and another three minutes to locate the remaining one, although none of the animals had left the area.

Since nocturnal sampling was unproductive, the sampling design was modified. Transects in the different types of habitats were sampled diurnally and the transect length was determined by 100 objects searched. Thirty-five transects were sampled using this modified sampling method. Unfortunately, heavy rains had preceded this sampling period and salamanders apparently were dispersed, so few were collected. Therefore, little information was obtained on the range of habitat types where salamanders could occur.

RESULTS AND DISCUSSION

Information on the general types of habitats occurring on northeast aspects that were located and examined in this research are given in Table 1. The range in elevation for all transects was about 8200 to 9500 ft with most of these between 8642-8949 ft. More of the sampling was done on moderate slopes (with slopes of about 19 to 20%). These slopes were most commonly found in our sampling area and probably depict the most common slope type in the Lincoln National Forest. There was a considerable range in vegetal cover; canopy, shrubs and ground. As anticipated, there was generally an inverse relationship between canopy cover and midstory cover, obviously related to competition for light and space. The relationship between midstory cover and ground story cover was slightly more variable, however, generally there was also an inverse relationship between these cover types. When midstory cover was higher, ground story cover was typically lower, so canopy cover and ground story cover appear to be positively related.

Possibly because of the history of logging in this area and natural events like fires, the average diameter at breast height (D. B. H. in inches) for all transects was similar. The mean values ranged from 9 to 12 inches. The range in soil moisture was considerable over all transects. However, gentle slopes typically have the moistest soil (60%); moderate slopes were lower, (about 39%) and steep slopes had the lowest average soil moisture (34%). Soil pH values were similar for all transects. The average values for soil pH indicate that the soils of the Sacramento Mountains are slightly

Table 1. Summarization of habitat characteristics (range, mean ±S.D.) for all diurnal transects (n=126) located on northeast aspects.

	Elevation (ft)	% Slope	% Cover			D. B. H. (in)
			Canopy (>3m)	Shrubs (1-3m)	Ground (<1m)	
I. GENTLE SLOPES						
A. Bottom (n=5)						
1. Range	8450-9320	9-10	40-80	10-50	40-90	7-14
2. Mean (±SD)	8802 (±318)	10 (±0.4)	60 (±16)	34 (±17)	61 (±22)	10 (±3)
B. Middle (n=5)						
1. Range	8550-9350	9-10	30-80	15-65	30-95	8-15
2. Mean (±SD)	8864 (±300)	10 (±0.4)	57 (±20)	39 (±20)	51 (±27)	13 (±3)
C. Top (n=5)						
1. Range	8550-9400	9-10	50-60	15-50	10-90	6-10
2. Mean (±SD)	8926 (±286)	10 (±0.4)	56 (±25)	39 (±16)	37 (±36)	9 (±3)
II. MODERATE SLOPES						
A. Bottom (n=26)						
1. Range	8200-9400	15-25	15-95	2-80	10-90	3-30
2. Mean (±SD)	8848 (±335)	20 (±4)	58 (±19)	32 (±22)	67 (±28)	12 (±6)
B. Middle (n=26)						
1. Range	8350-9400	15-25	40-90	5-80	5-95	4-25
2. Mean (±SD)	8922 (±316)	20 (±4)	67 (±14)	38 (±21)	54 (±28)	11 (±4)
C. Top (n=26)						
1. Range	8500-9500	15-25	2-95	5-80	5-90	4-25
2. Mean (±SD)	8998 (±292)	19 (±4)	70 (±18)	30 (±20)	48 (±28)	10 (±5)

Table 1. (Continued)

	Elevation (ft)	% Slope	% Cover			D. B. H. (in)
			Canopy (>3m)	Shrubs (1-3m)	Ground (<1m)	
III. STEEP SLOPES						
A. Bottom (n=11)						
1. Range	8400-9060	30-45	25-80	5-60	2-90	8-20
2. Mean (±SD)	8746 (±222)	33 (±5)	59 (±19)	30 (±16)	49 (±31)	12 (±4)
B. Middle (n=11)						
1. Range	8450-9100	30-35	6-95	10-50	2-90	7-15
2. Mean (±SD)	8813 (±218)	31 (±2)	76 (±11)	31 (±12)	61 (±27)	11 (±3)
C. Top (n=11)						
1. Range	8500-9140	30-32	55-95	10-60	15-95	6-20
2. Mean (±SD)	8881 (±224)	30 (±1)	78 (±11)	27 (±19)	69 (±29)	11 (±4)

acidic with mean values from 6.0 to 6.9.

In Tables 2 and 3, transects are grouped on the basis of whether or not salamanders were collected. Of the total 126 transects examined, salamanders were found on 55 or 44% of these (Table 3). Probably since moderate slopes were the most commonly sampled, total numbers of salamanders collected were highest for these. However, when comparisons are made for the average numbers of salamanders per transect for the different types of slopes, steep slopes had the highest average numbers of salamanders per transect (Table 3). Comparisons of elevation for transects on gentle, moderate and steep slopes with and without salamanders indicate that salamanders are found at higher elevations. The only exception to this is the top areas of steep slopes where transects without salamanders had a slightly higher average elevation (Table 2). This is possibly related to the levels of soil moisture, since the top transects along steep slopes typically had the lowest soil moisture content. The overall average elevation for all transects, regardless of slope or position, was 8888 (±297.6) ft (Table 4). When overall elevations are compared by a One-Way Analysis of Variance for the two categories of transects, a highly significant difference is obtained ($F_{(.01)1,123} = 10.93^{**}$). Elevation is apparently an important habitat characteristic for Aneides hardii with an average value of 8986 (±294.2) ft on transects with salamanders and 8813 (±280.8) on transects without salamanders.

Figure 1 shows the actual distributions of elevations for the transects where salamanders were found and where they were not found. This figure demonstrates that transects with salamanders were more numerous at high elevations than transects without salamanders. When transects that

Table 2. Summarization of habitat characteristics (range, mean ±S.D.) for diurnal transects without salamanders (n=70) located on northeast aspects.

	Elevation (ft)	% Slope	% Cover			D. B. H. (in)	% Moisture	pH
			Canopy (>3m)	Shrubs (1-3m)	Ground (<1m)			
I. GENTLE SLOPES								
Pooled:								
A. Bottom (n=3)								
B. Middle (n=4)								
C. Top (n=4)								
1. Range	8450-8900	9-10	45-80	10-65	10-95	7-15	21-100	60-70
2. Mean (±SD)	8742 (±140)	10 (±0.4)	61(±11.4)	34(±17.8)	44(±32.2)	11 (±3.4)	60 (±27.9)	6.3
II. MODERATE SLOPES								
A. Bottom (n=18)								
1. Range	8200-9400	15-25	15-75	2-80	10-95	4-25	4-177	60-70
2. Mean (±SD)	8758 (±301)	20 (±4.2)	51(±17.4)	37(±24)	70(±27.4)	12 (±5.5)	43 (±45.9)	6.2
B. Middle (n=14)								
1. Range	8350-9450	15-25	40-85	5-75	5-80	4-15	7-100	5.5-7.0
2. Mean (±SD)	8817 (±309)	19 (±4.7)	63(±14.4)	37(±19.2)	48(±27.2)	10(±2.8)	41 (±28.8)	6.3
C. Top (n=16)								
1. Range	8600-9500	15-25	20-95	5-80	5-90	5-25	1-100	6.0-7.0
2. Mean (±SD)	8949 (±280)	19 (±3.5)	64(±20.4)	27(±20.4)	36(±26.1)	9 (±4.7)	33 (±27.8)	6.5
III. STEEP SLOPES								
A. Bottom (n=5)								
1. Range	8400-9060	30-45	30-75	15-60	15-95	8-17	21-91	6.5-7.0
2. Mean (±SD)	8642 (±252)	34 (± 6.3)	52(±17.5)	32(±19.5)	64(±30.2)	11 (±3.6)	38 (±38.9)	6.9
B. Middle (n=3)								
1. Range	8600-9100	30	70-85	25-50	20-90	10-15	25-50	6.0-6.5
2. Mean (±SD)	8792 (±269)	30(±0)	77(±2.6)	35(±13.2)	45(±39.0)	12 (±2.9)	37 (±17.7)	6.2
C. Top (n=4)								
1. Range	8650-9140	30-32	80-85	5-40	2-40	6-15	21-31	6.0-7.0
2. Mean (±SD)	8897 (±235)	31(±1.0)	81(±2.5)	21(±15.0)	18(±16.4)	10 (±3.9)	26 (±4.7)	6.5

Table 3. Summarization of habitat characteristics (range, mean ± S.D.) for all diurnal transects with salamanders (n=55) located on northeast aspects.

	Number of Salamanders	Elevation (ft)	% Slope	% Cover			D. B. H. (in)	% Moisture	pH
				Canopy (>3m)	Shrubs (1-3m)	Ground (<1m)			
I. GENTLE SLOPES									
Pooled:									
A. Bottom (n=2)	6								
B. Middle (n=1)	5								
C. Top (n=1)	5								
1. Range	1-6	8720-9400	10	30-70	30-50	60-75	6-12	25-81	6.0-7.0
2. Mean (±SD)	4.0	9200 (±322)	10 (±0)	48(±17.0)	45(±10.0)	64(±7.5)	9 (±2.9)	52 (±28.6)	6.3
II. MODERATE SLOPES									
A. Bottom (n=8)	28								
1. Range	1-7	8600-9400	15-25	60-95	10-40	15-90	3-30	30-79	6.0-7.0
2. Mean (±SD)	3.5	9050 (±337)	21 (±3.2)	75(±12.2)	21(±11.3)	61(±29.0)	12 (±8.0)	53 (±24.6)	6.3
B. Middle (n=12)	50								
1. Range	1-9	8700-9450	15-25	40-90	10-80	10-95	5-25	21-62	5.5-6.5
2. Mean (±SD)	4.2	9045 (±289)	21 (±3.8)	71(±13.8)	40(±24.5)	64(±27.5)	12 (±5.0)	45 (±17.7)	6.0
C. Top (n=10)	31								
1. Range	1-7	8500-9500	15-25	60-95	5-70	60-90	4-25	35-85	6.0-7.0
2. Mean (±SD)	3.1	9077 (±324)	19 (±4.6)	78(±10.6)	34(±18.8)	68(±19.3)	12 (±6.4)	58 (±18.3)	6.2
III. STEEP SLOPES									
A. Bottom (n=6)	24								
1. Range	1-7	8550-9000	30-35	25-80	5-60	30-95	10-20	19-48	6.0
2. Mean (±SD)	4.0	8833 (±166)	31 (±2.0)	64(±20.4)	23(±19.9)	73 (±29.2)	13 (±3.8)	33 (±14.6)	6.0
B. Middle (n=8)	40								
1. Range	1-9	8450-9250	30-35	60-95	10-50	35-95	7-15	16-42	6.0-6.5
2. Mean (±SD)	5.0	8846 (±255)	32 (±2.1)	76(±12.9)	29(±12.9)	67 (±21.0)	10 (±2.6)	27 (±11.6)	6.2
C. Top (n=7)	34								
1. Range	2-11	8500-9100	30-33	55-95	10-60	25-90	8-20	11-42	6.0-7.0
2. Mean (±SD)	4.9	8871 (±238)	31 (±1.1)	71(±14.0)	35(±15.6)	66 (±21.9)	12 (±3.9)	28 (±138)	6.2

Table 4. Statistical comparisons (One-Way Analysis of Variance) of different habitat characteristics ($\bar{x} \pm$ S.D.).

I. Elevation (ft)

A. All transects = 8888 (±297.6)

1. Transects without salamanders = 8813 (±280.8)
2. Transects with salamanders = 8986 (±294.2) } ($F_{(.01)1,124} = 10.93^{**}$)
   a) Adjusted transects = 8990 (±273.2)
   b) Salamander sites = 8910 (±620.0) } ($F_{1,466} = 3.25^{n.s.}$)

II. Overstory - % Cover

A. All transects = 65.4 (±17.4) %

1. Transects without salamanders = 60.9 (±17.7) %
2. Transects with salamanders = 71.1 (±15.4) } ($F_{(.001)1,125} = 11.56^{***}$)
   a) Adjusted transects = 70.8 (±16.8) %
   b) Salamander sites = 72.5 (±18.6) % } ($F_{1,467} = 1.07^{n.s.}$)

III. Midstory - % Cover

A. All transects = 32.4 (±19.5) %

1. Transects without salamanders = 32.4 (±20.3) %
2. Transects with salamanders = 32.4 (±18.5) % } ($F_{1,126} = .007^{n.s.}$)
   a) Adjusted transects = 32.3 (±16.9) %
   b) Salamander sites = 30.9 (±18.9) % } ($F_{1,446} = 3.13^{n.s.}$)

IV. Ground Story - % Cover

A. All transects = 56.5 (±28.8) %

1. Transects without salamanders = 49.1 (±30.8)%
2. Transects with salamanders = 65.9 (±23.0)% } ($F_{(.001)1,126} = 11.32^{***}$)
   a) Adjusted transects = 65.3 (±22.0) %
   b) Salamander sites = 65.1 (±26.9) % } ($F_{1,444} = 1.76^{n.s.}$)

Table 4. (Continued)

V. % Slope

A. All Transects = 22.0 (±8.0) %

1. Transects without salamanders = 20.2 (±7.0) %
2. Transects with salamanders = 23.7 (±7.0) %

} ($F_{(.01)1,125} = 7.55^{**}$)

a) Adjusted transects = 25.2 (±7.3) %
b) Salamander sites = 24.1 (±7.4) %

} ($F_{1,450} = 2.38^{n.s.}$)

VI. D. B. H. (in)

A. All transects = 11.1 (±4.6)

1. Transects without salamanders = 10.7 (±4.3)
2. Transects with salamanders = 11.5 (±5.1)

} ($F_{1,126} = 0.87^{n.s.}$)

a) Adjusted transects = 11.5 (±4.6)
b) Salamander sites = 11.4 (±6.1)

} ($F_{1,467} = 1.16^{n.s.}$)

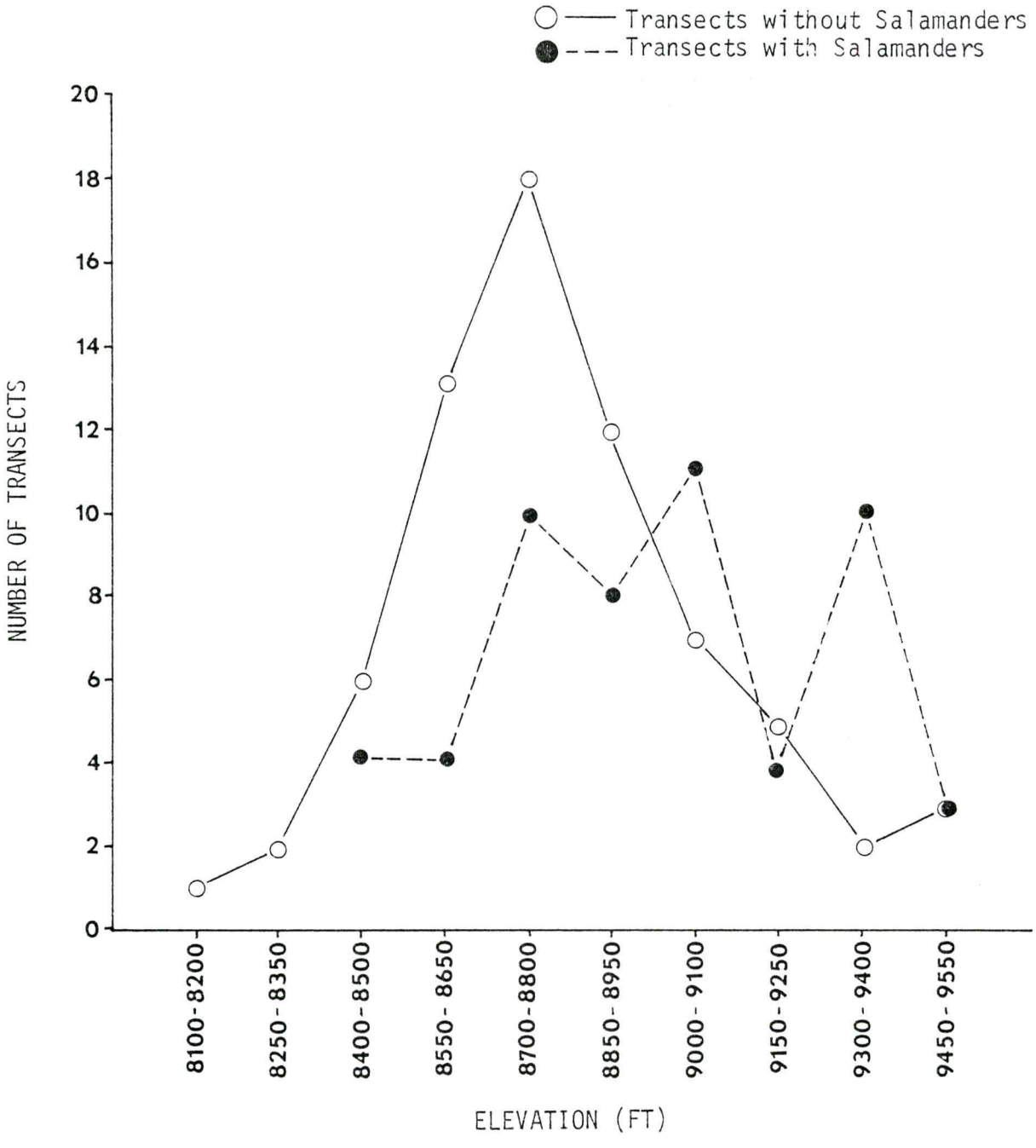

Figure 1. Distribution of elevations (ft) for the transects with and without salamanders.

occurred at elevations of less than 8850 ft are compared, 60% of those without salamanders and 32% of the transects with salamanders were found below this elevation.

Average values for percent slope given in Tables 2 and 3 are quite similar for transects with and without salamanders. However, when all slopes for transects with and without salamanders are grouped and compared (Table 4), salamanders were found more frequently in areas with a higher slope ($F_{(.01)1,125} = 7.55^{**}$). Transects with salamanders averaged a slope of 23.7% (±0.07), while those without salamanders averaged 20.2% (±0.07). The overall average slope for all transects sampled (n=126) was 22% (±0.08). Figure 2 gives the actual distributions of slopes for transects with and without salamanders. About 65% of the transects without salamanders occurred at slopes of 20 or less, while 43% of the transects where salamanders were located had slopes of 20 or less.

The percent of overstory or canopy cover and ground story cover were both very important habitat factors for salamanders. With two exceptions, gentle slopes and tops of steep slopes, canopy cover was considerably higher on all slopes where salamanders were present (Tables 2 and 3). In one case, the middle areas of steep slopes, the canopy cover was similar for transects with and without salamanders.

In the three instances where the average values for canopy cover were similar or higher on transects without salamanders than on those with salamanders, ground cover was considerably lower. With only one exception, the bottom areas of moderate slopes, ground story cover was considerably higher on transects with salamanders. The largest differences in ground story cover were found on the tops of moderate and steep slopes (Tables 2 and 3).

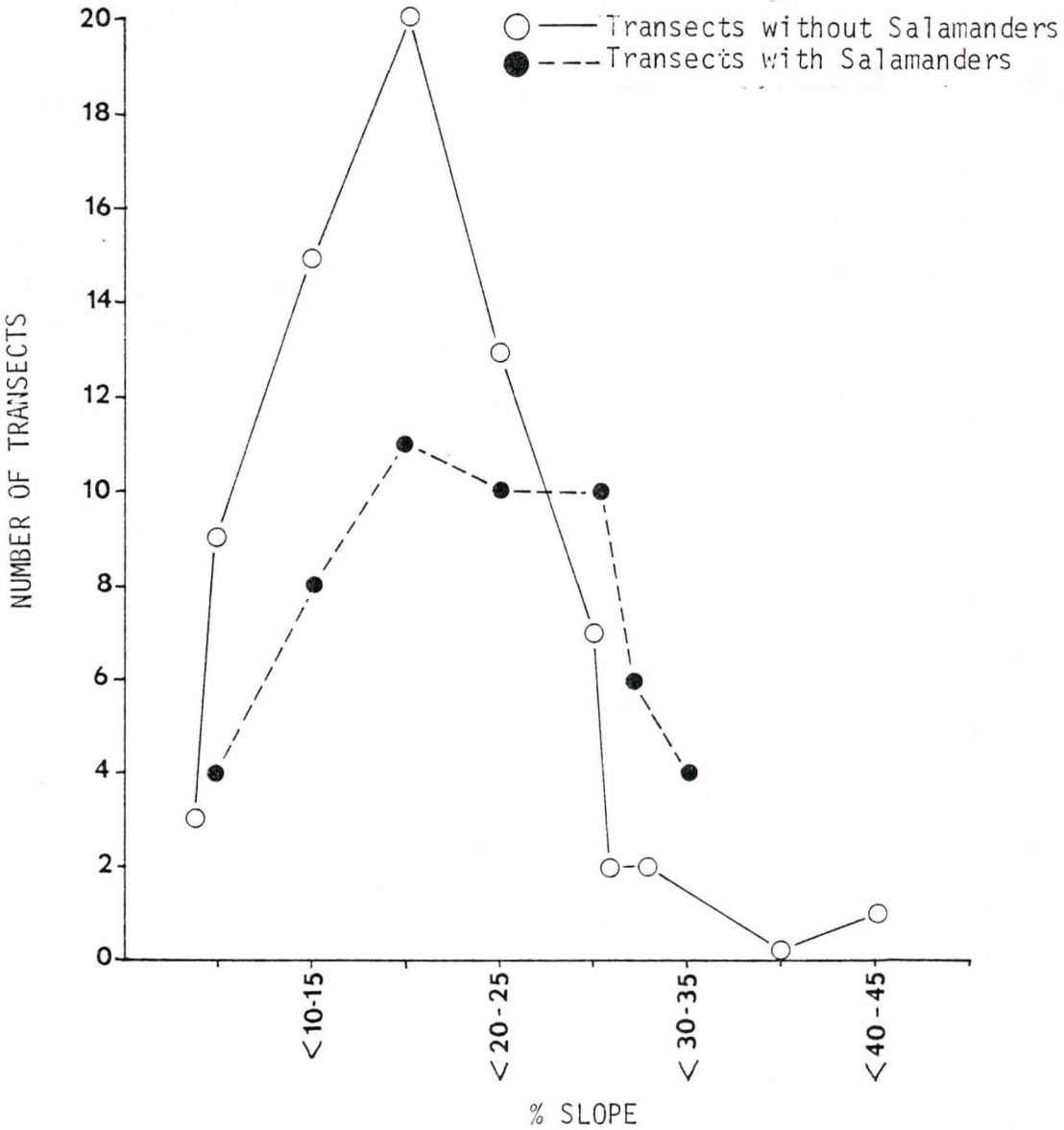

Figure 2. Distribution of percent slope for the transects with and without salamanders.

Although the differences in soil moisture are not significant because of their variability, average soil moisture content was considerably higher on the tops of moderate slopes with salamanders and slightly higher on the tops of steep slopes with salamanders. This indicates a general relationship between ground cover, soil moisture and the presence or absence of salamanders. When transects with and without salamanders were statistically examined for differences in overstory and ground story cover (Table 4), transects with salamanders averaged significantly higher values for both cover types. The overall average overstory cover for all transects was 65.4% (±17.4) and transects with salamanders 71.1% (±15.4) and those without, 60.9% (±17.7). The differences between overstory cover was very highly significant ($F_{(.01)1,125} = 11.56^{***}$), indicating that this is an important variable to consider in describing and maintaining the Sacramento Mountain salamander's optimum habitat. Similarly, the difference between ground story cover for transects with and without salamanders was very highly significant ($F_{(.01)1,126} = 11.32^{***}$). The average ground story for all transects was 56.5% (±28.8), while those with salamanders averaged 65.9% (±23.0) and those without 49.1% (±30.8). So ground story is also an important habitat factor. This is not surprising since there appears to be a direct positive relationship between these two cover types.

Figures 3 and 4 depict the distribution of transects in relation to the % overstory and ground story cover. When these distributions are compared to determine the proportions of transects that had overstory and ground story cover of 60% or less, 40% (overstory) and 54% (ground story) of the transects without salamanders were below this value. For the tran-

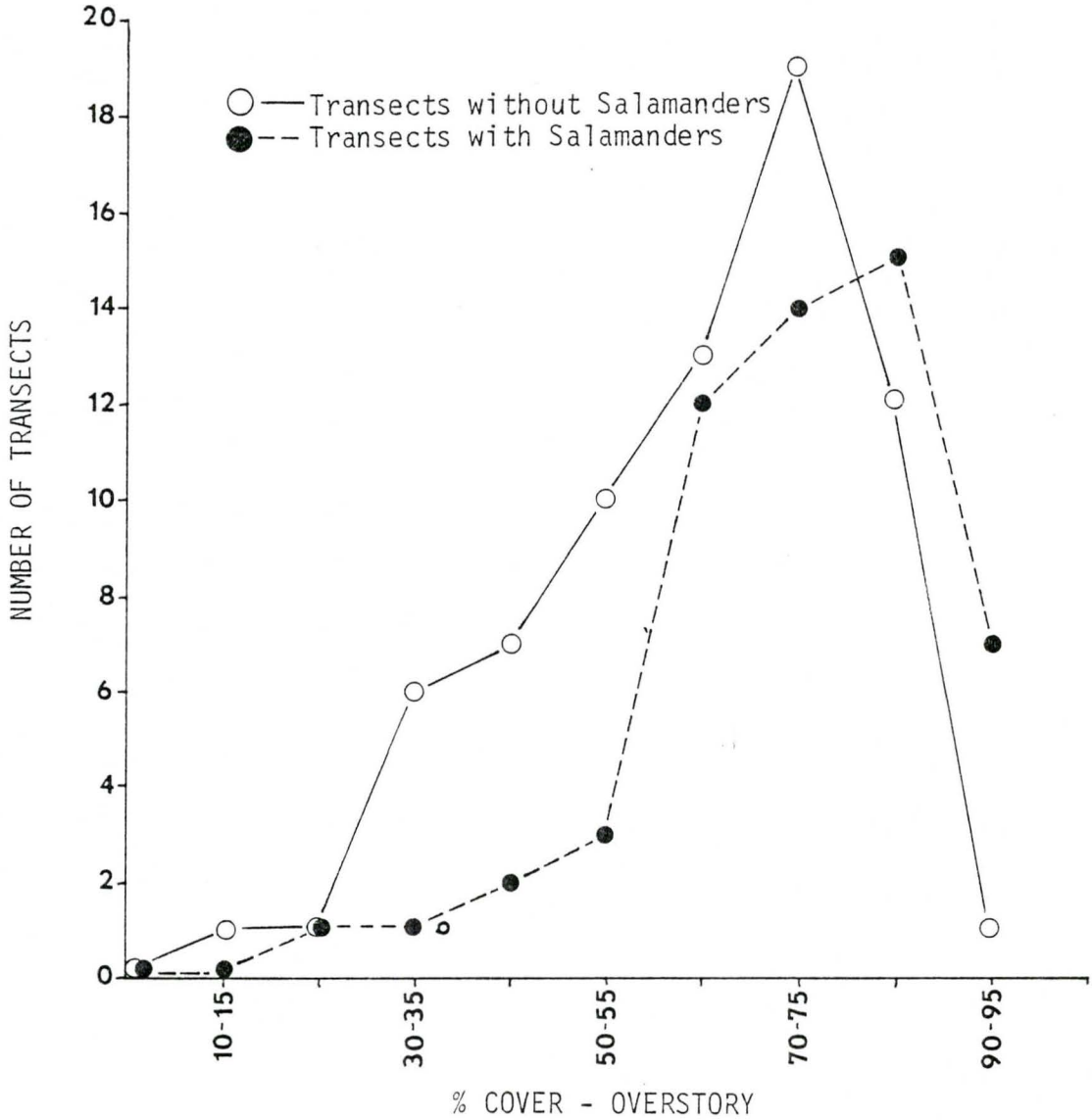

Figure 3. Distribution of percent overstory cover for the transects with and without salamanders.

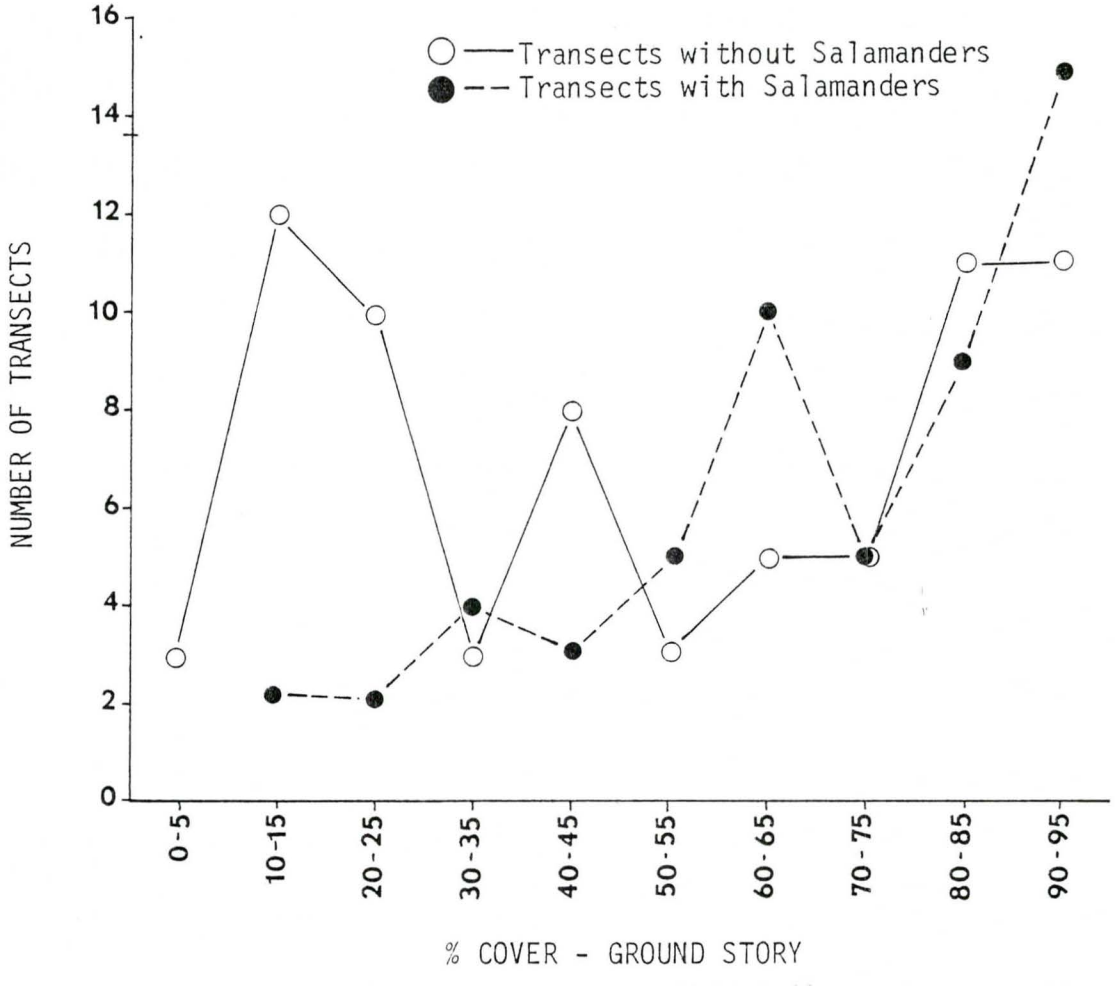

Figure 4. Distribution of percent ground story cover for the transects with and without salamanders.

sects with salamanders, 13% had overstory and 33% ground story cover below this percentage.

Midstory appeared to be extremely variable for transects with and without salamanders at different locations on gentle, moderate and steep slopes (Tables 2 and 3). The overall average for all transects was 32.4% (±19.5) for the midstory cover (Table 4). Average values for all transects without salamanders and with salamanders were the same, 32.4% (±20.3) and 32.4% (±18.5), respectively. Figure 5 shows the distributions of % cover for midstory vegetation on transects with and without salamanders. There was a slight tendency for transects without salamanders to have the higher proportion of midstory cover less than 30%. About 48% of the transects without salamanders had midstory cover of less than 30%, while about 36% of the transects with salamanders were below this value.

As mentioned previously, the average D. B. H. differed little over all transects in the sampling area (Tables 2, 3 and 4). Although transects where salamanders were collected had a slightly higher D. B. H., 11.5 (±5.1) in, than those without, 10.7 (±4.3) in; these differences were not significant. Figure 6 shows the distribution of D. B. H. for transects with and without salamanders. A slightly higher percentage of transects without salamanders had a D. B. H. of 9 in or less, 39%, than those with salamanders, 30%.

Adjusted Salamander Transect Data and Salamander Site Data

Unadjusted salamander transects were next weighted to evaluate the accuracy of the transect data in accurately depicting the importance of the various habitat factors. This was accomplished by considering the importance

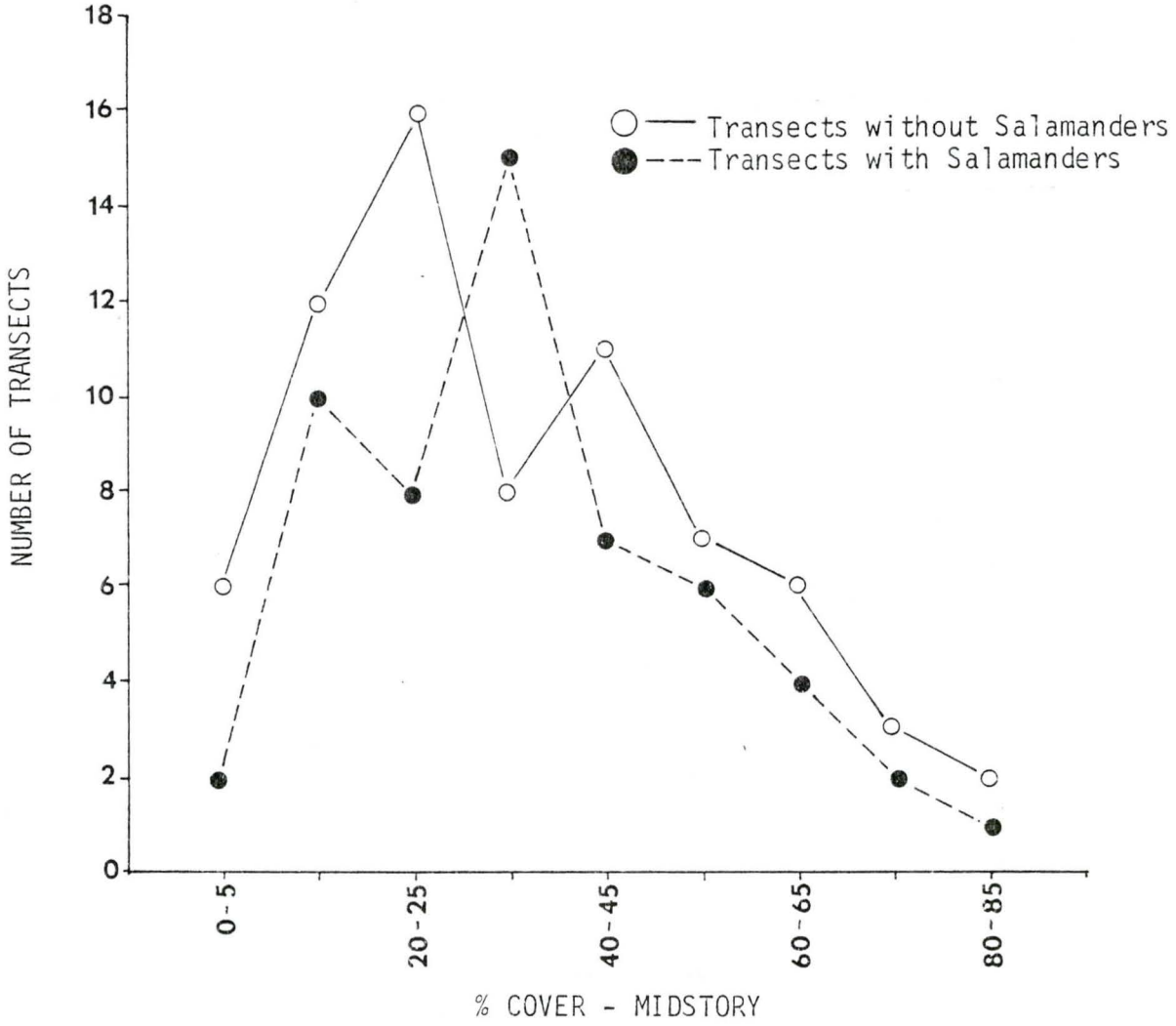

Figure 5. Distribution of percent midstory cover for the transects with and without salamanders.

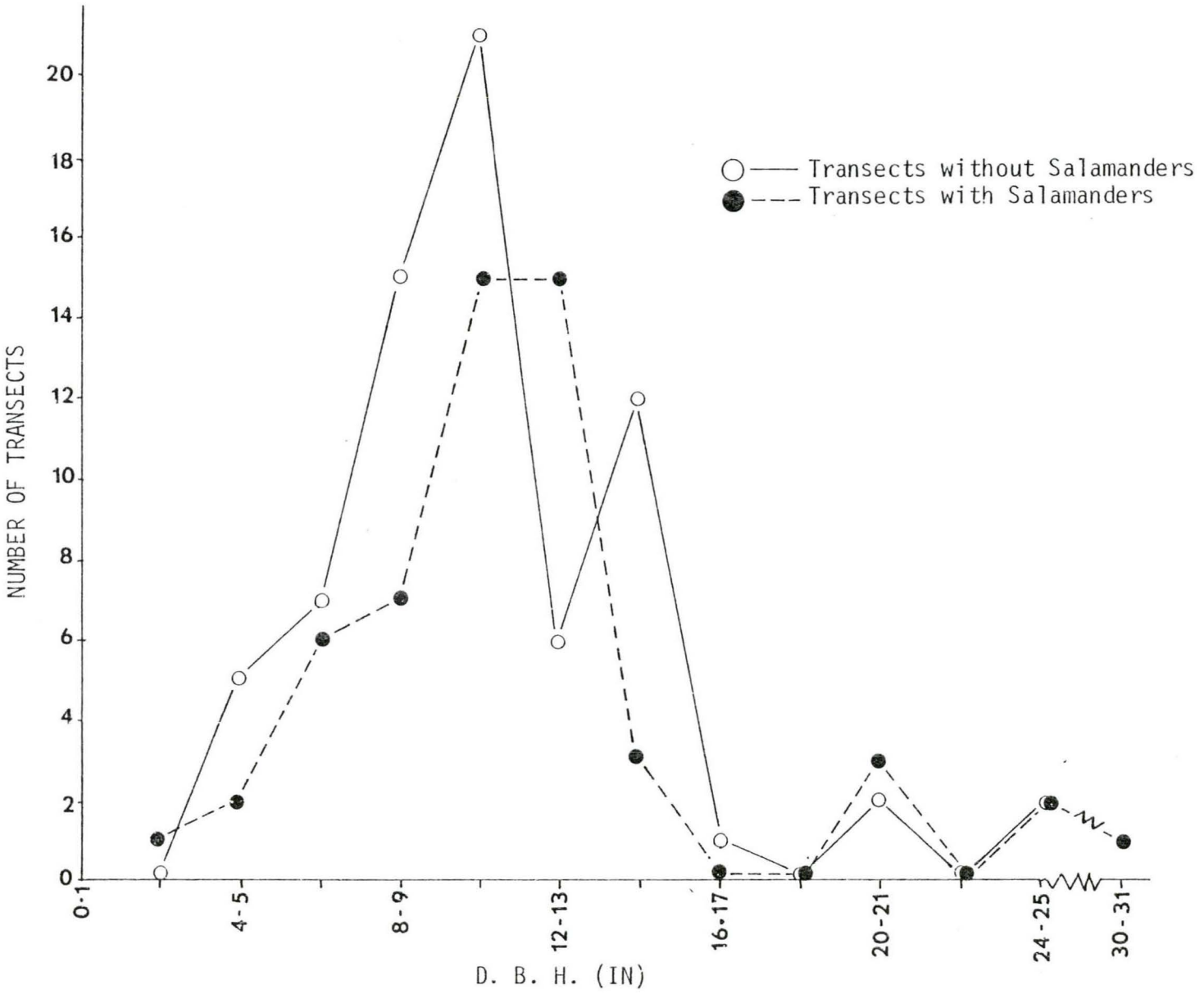

Figure 6. Distribution of D. B. H. (in) for the transects with and without salamanders.

of the habitat measurements to be directly related to the number of salamanders collected on the transect. Table 4 shows that unadjusted salamander transect data and adjusted transect data were very similar. Only for % slope was there a notable difference, the unadjusted transects had a mean value of 23.7 (±7.0)%, while the weighted transects averaged 25.2 (±7.3%).

Adjusted transect information was then compared statistically with data collected from the particular sites along the transects where salamanders were found. In general, the adjusted transect data adequately measured the importance of the habitat factors, since these values were similar to those for actual salamander site data. This is an important consideration, for it suggests that transect data alone may be used for evaluating salamander habitat. This general method is less costly and time consuming than taking detailed data for each salamander collection site along the transect.

Overstory cover was slightly higher for the actual sites where salamanders were collected, while elevation, midstory cover and slope were slightly lower. The distribution of salamanders in relation to elevation, % slope, % overstory, % ground story, % midstory and D. B. H. for adjusted transects and specific collection sites along transects are shown, respectively, in Figures 7, 8, 9, 10, 11 and 12.

Figure 7 indicates that 79% of the salamanders along transects were found between elevations of 8700 to 9400 ft and 73% of the salamanders were actually collected at sites that ranged from 8700 to 9250 ft. Although information in the literature suggests Aneides hardii are not likely to

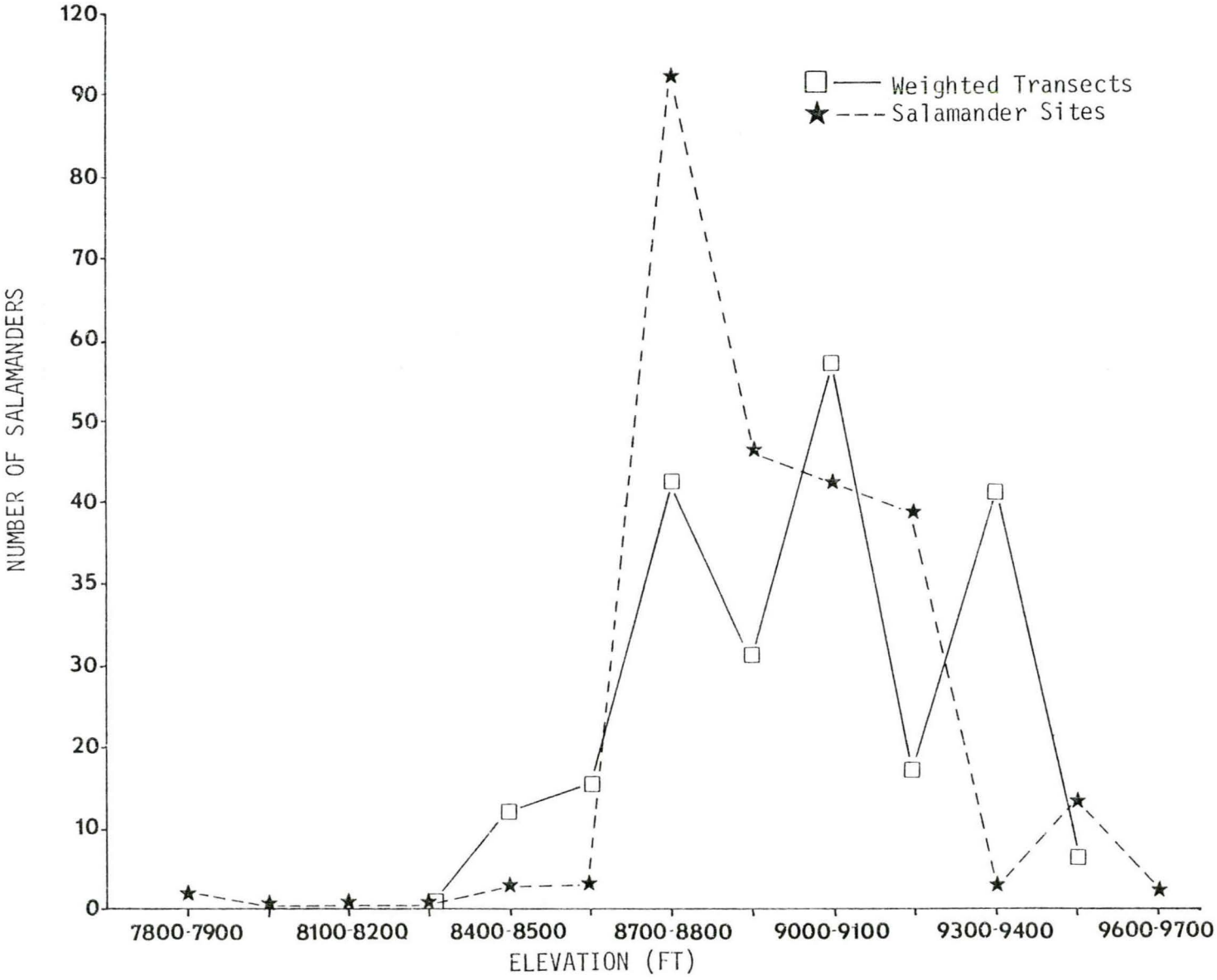

Figure 7. Distribution of elevations (ft) for weighted transects and salamander collection sites.

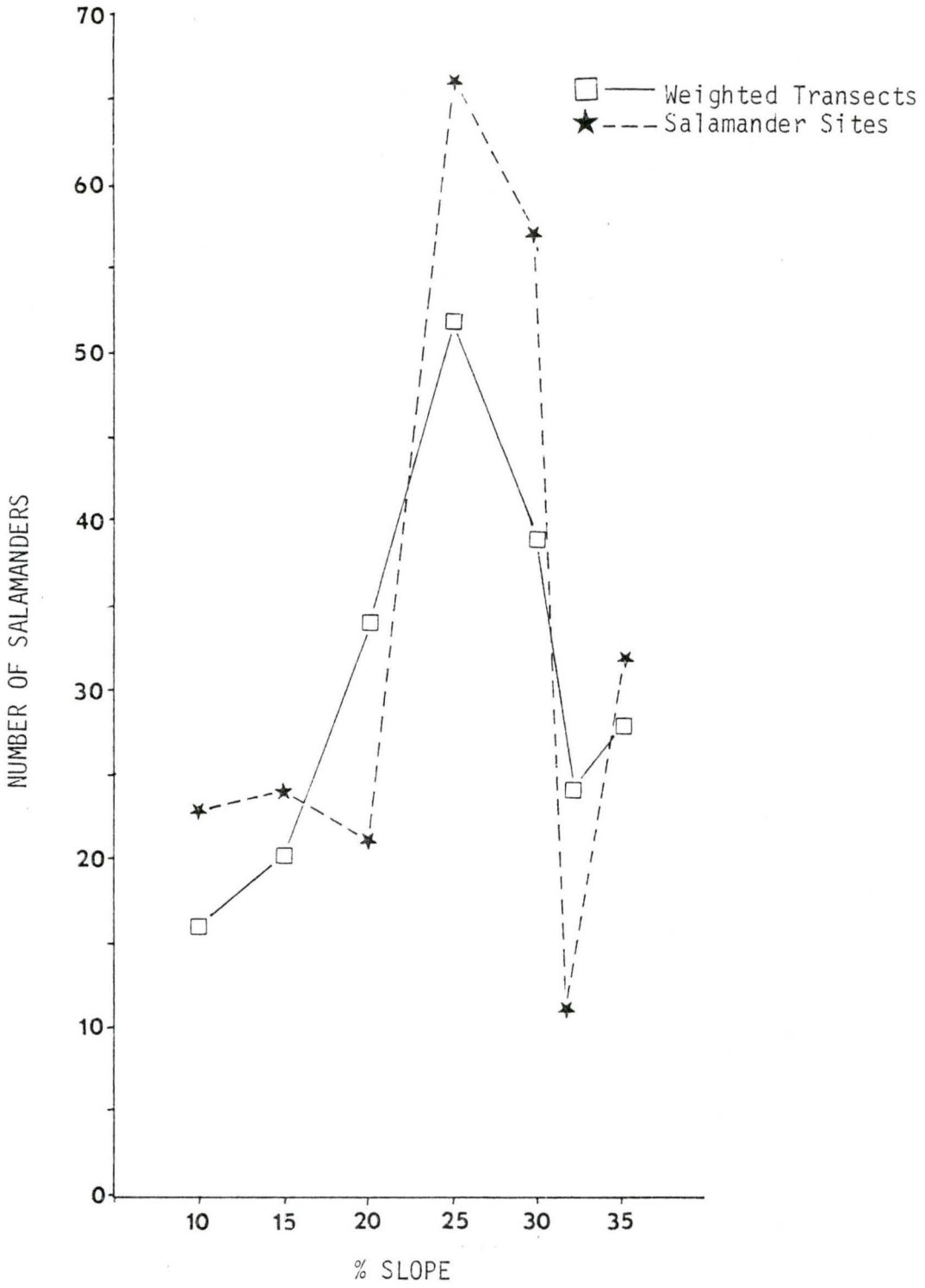

Figure 8. Distribution of percent slope for weighted transects and salamander collection sites.

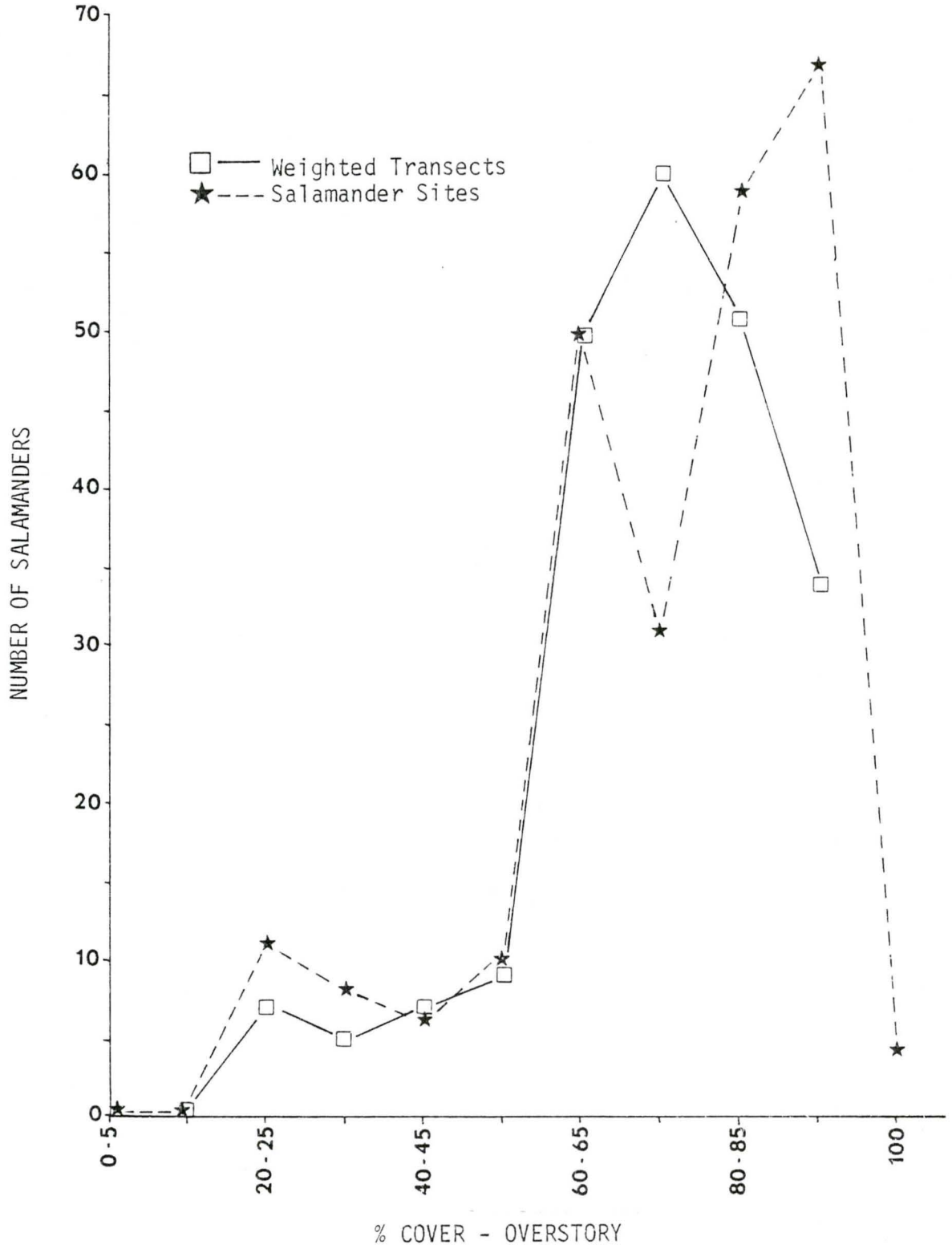

Figure 9. Distribution of percent overstory cover for weighted transects and salamander collection sites.

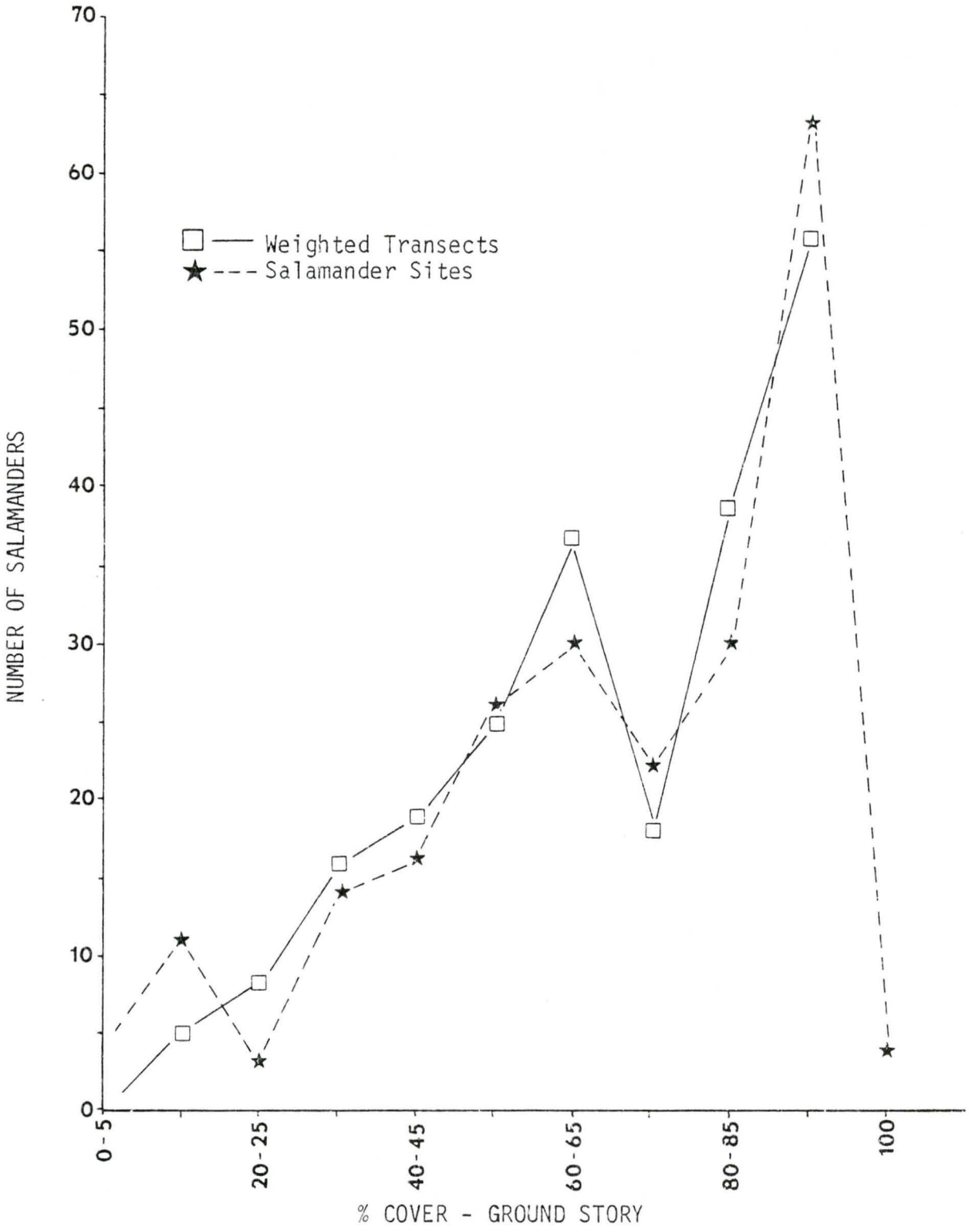

Figure 10. Distribution of percent ground story cover for weighted transects and salamander collection sites.

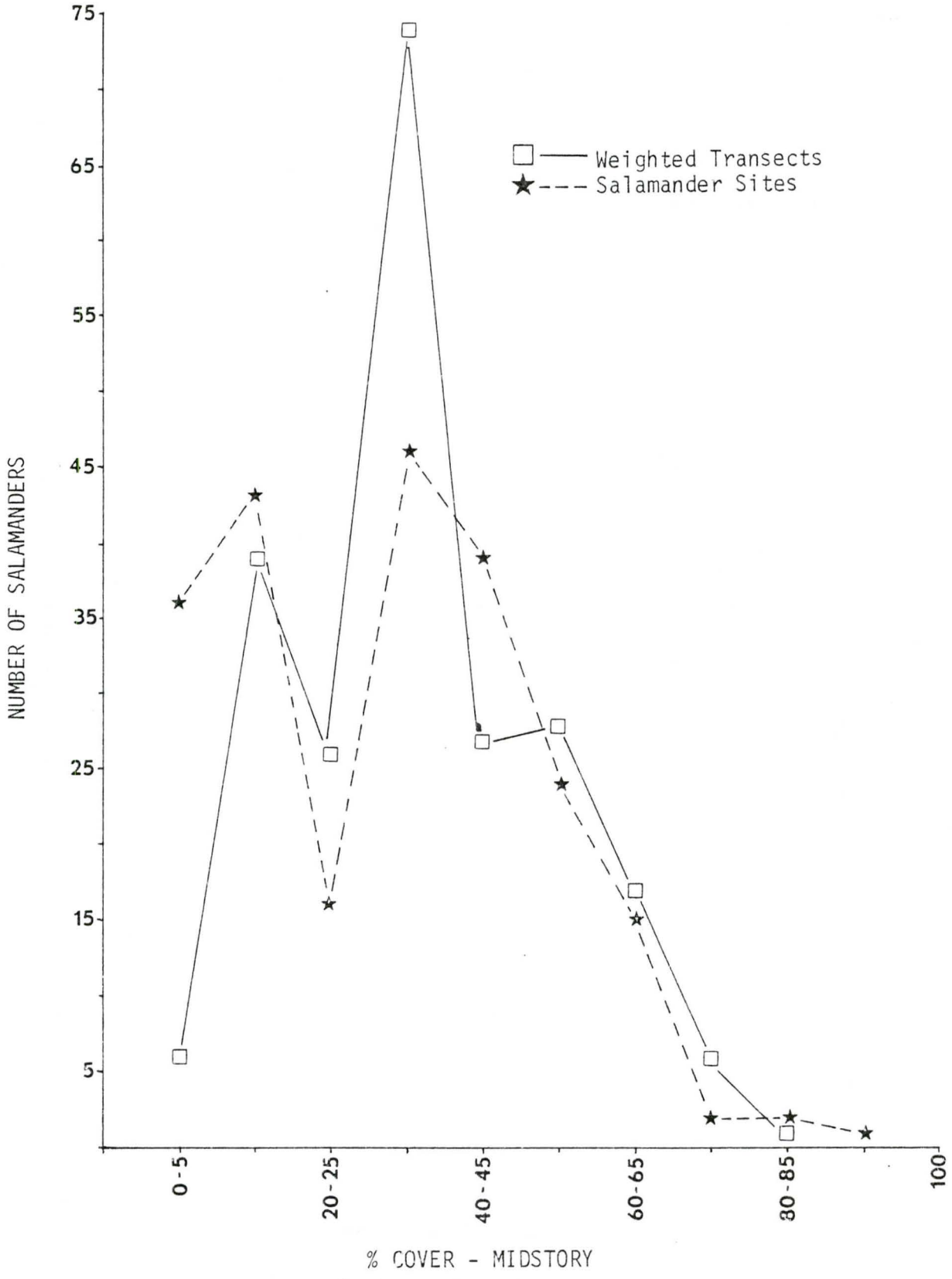

Figure 11. Distribution of percent midstory cover for weighted transects and salamander collection sites.

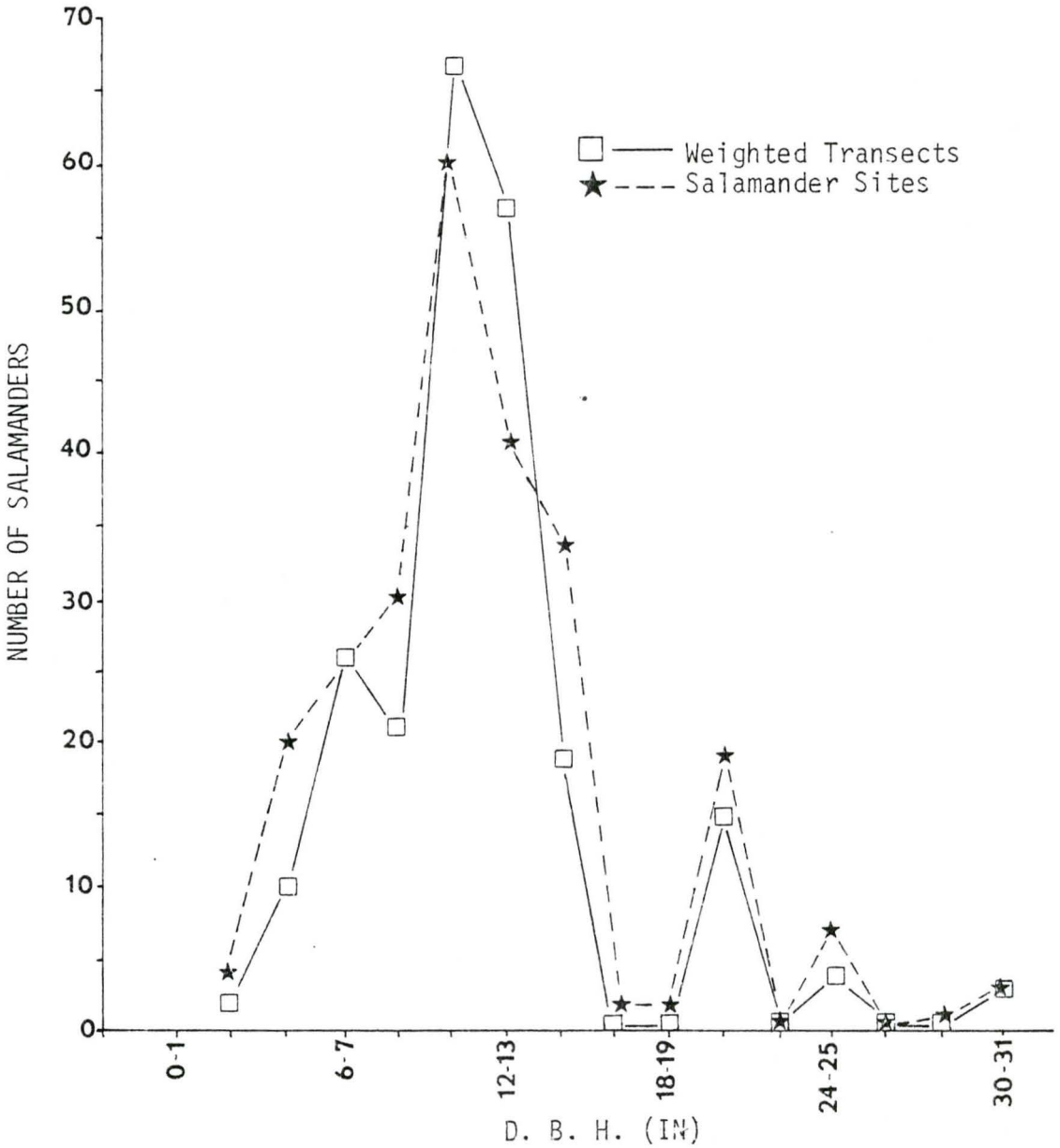

Figure 12. Distribution of D. B. H. (in) for weighted transects and salamander collection sites.

occur below 8600 ft, they were collected from elevations of 7800-7900 ft. Apparently salamanders can be found at lower elevations if other habitat factors are appropriate. Adequately evaluating the lower ranges of elevation where salamanders may occur was not accomplished in this study. The nocturnal sampling was designed to evaluate this aspect, and nocturnal sampling was ineffective. Based on this small sample size, we can only suggest that salamanders do occur at lower elevations.

For % slope (Figure 8), the adjusted transect data and salamander site data shows a very similar distribution of salamanders. As mentioned, the % slope for actual salamander collection sites was slightly lower than that for adjusted transects.

Slightly more salamanders were actually collected from sites with higher canopy cover than is indicated by the adjusted transect data (Figure 9). The distribution of salamanders in relation to ground story cover was very similar for the adjusted transect data and salamander site data (Figure 10). Comparisons of midstory cover (Figure 11) indicate that the actual sites where the salamanders were collected had slightly lower shrub cover than the adjusted transects depict.

Differences between adjusted transects and salamander sites for D. B. H. were extremely minor (Figure 12); similar numbers of salamanders were collected from transects and actual sites along transects.

Dominant Objects Along Transects and Density of Objects

Table 5 provides information on the major types of objects on the ground along the transects with and without salamanders and the average distance between objects. With the exception of gentle slopes (12% of the

Table 5. Summarization of the dominant objects and the average distance ($\bar{x}$, ±S. D.) between objects for diurnal transects with and without salamanders.

	Dominant objects along transects						Distance (m) between objects
	Logs	Rocks	Sticks	Bark	Stumps	Aspen logs	
I. TRANSECTS WITHOUT SALAMANDERS							
A. Gentle slopes	4%	42%	37%	-	-	18%	1.09 (± 1.04)
Bottom	-	43%	29%	-	-	29%	1.33 (± 1.15)
Middle	11%	44%	33%	-	-	11%	1.00 (± 1.00)
Top	-	38%	50%	-	-	13%	1.00 (± 1.00)
B. Moderate slopes	19%	39%	39%	2%	1%	1%	1.35 (± 1.16)
Bottom	22%	39%	37%	-	3%	-	1.36 (± 1.17)
Middle	26%	35%	35%	-	-	-	1.18 (± 1.09)
Top	9%	40%	43%	6%	-	3%	1.48 (± 1.22)
C. Steep slopes	12%	48%	36%	-	4%	-	1.57 (± 1.25)
Bottom	9%	45%	44%	-	9%	-	1.01 (± 1.00)
Middle	-	60%	40%	-	-	-	1.25 (± 1.12)
Top	22%	44%	33%	-	-	-	2.50 (± 1.58)
II. TRANSECTS WITH SALAMANDERS							
A. Gentle slopes (pooled)	-	50%	33%	17%	-	-	1.13 (±1.06)
B. Moderate slopes	30%	40%	30%	1%	-	-	1.12 (±1.06)
Bottom	26%	37%	37%	-	-	-	1.22 (±1.10)
Middle	28%	38%	28%	3%	-	-	1.07 (±1.03)
Top	32%	40%	24%	-	-	-	1.10 (±1.05)
C. Steep slopes	31%	38%	24%	2%	2%	-	1.45 (±1.20)
Bottom	21%	36%	29%	7%	7%	-	1.43 (±1.20)
Middle	35%	41%	24%	-	-	-	1.56 (±1.25)
Top	36%	36%	21%	-	-	-	1.32 (±1.15)

total transects), conifer logs comprised a larger proportion of the objects on slopes with salamanders than without salamanders. This is especially true of steep slopes, where transects with salamanders had considerably more conifer logs along the bottom, middle and top portions. Aspen logs were considered a separate log category, since salamanders never were collected from areas with aspen logs. Evidently aspen logs occurred more frequently on gentle slopes in the sampling area and only 4 of the total 55 transects with salamanders were located there. On both transects with and without salamanders, rocks and sticks comprised a large proportion of the ground material. Surprisingly, salamanders were more frequently associated with bark on the ground than with stumps. The distance between objects for gentle slopes was similar for both types of transects. Both for moderate and steep slopes, the average distance between objects was less for transects with salamanders, indicating a greater density of cover material. All areas along moderate slopes with salamanders had a greater density of objects. The abundance of cover on steep slopes was variable along the bottom, middle and upper contours for transects with and without salamanders. It appears that on steep slopes the presence of suitable cover, conifer logs, is a more important habitat factor than cover density. The upper contours on steep slopes without salamanders had more logs, but the distances between them was considerable, limiting their value as appropriate cover. When all of the transects with salamanders and without salamanders are separately grouped and compared, the average distance between objects for transects without salamanders was 1.35 (±0.96) meters and those with salamanders, 1.24 (±0.95) m. Because of the variability on different slopes, these differences were not significant ($F_{1,125} = 0.39$). A similar

comparison for conifer logs demonstrates that they were a major component on 64% of the transects with salamanders and 39% of the transects without salamanders.

Projections on the estimated salamander density per 100 m were made using information on salamander numbers and the distance between objects (Table 6). The values were highest for gentle slopes, but little confidence can be placed on this estimate because of the small number of gentle slopes. This data suggests that the middle contours of moderate slopes and the bottom contours of steep slopes have the highest concentrations of salamanders. However, the large standard deviations associated with the means indicate that the density estimates are very preliminary. As discussed, conifer logs were more common on the transects with salamanders (Table 5). Information presented in Table 6 clearly shows that salamanders were consistently associated with conifer logs, regardless of slope type. Clumping or aggregating of salamanders was very common along all contours and slopes. Salamanders were more likely to be clumped in habitats that were less suitable, gentle slopes and steep slopes. When salamanders were aggregated, generally three or more were collected at the same site. On all of the slopes, 50% or more of the transects had at least three salamanders occurring together.

To better assess the prevalence of clumping in Aneides hardii on the sampling area, the number of salamanders that were aggregated was divided by the total number of salamanders. Again, regardless of contour and slope, a high proportion of the total salamanders located were clumped. The information on the clumped distributions of salamanders and the importance of conifer logs confirms the conclusions of other researchers, that were based

Table 6. Estimated density and prevalence of aggregating of Aneides hardii. Also percentages of the total salamanders that were collected from different types of ground cover.

	Number of salamanders/ 100 m	Objects					% Transects clumping	% Transects >2 salamanders per clump	Clumped / Total Number
		In logs or under bark	Rocks	Sticks	Bark on ground	Stumps			
A. Gentle Slopes (pooled)	42 (±65)	100%	-	-	-	-	75%	100%	94%
B. Moderate Slopes	35 (±59)	71%	16%	4%	2%	7%	47%	69%	58%
Bottom	17 (±41)	53%	39%	4%	-	4%	50%	75%	57%
Middle	51 (±71)	78%	6%	2%	6%	8%	50%	83%	66%
Top	31 (±56)	81%	3%	6%	-	10%	40%	50%	52%
C. Steep Slopes	24 (±49)	76%	10%	2%	10%	-	70%	72%	70%
Bottom	51 (±71)	70%	13%	4%	13%	-	50%	100%	65%
Middle	14 (±37)	80%	10%	3%	3%	-	88%	57%	75%
Top	12 (±37)	79%	6%	-	15%	-	71%	60%	71%

on qualitative observations. Because salamanders have an aggregated distribution, valid measurements of population density will be very difficult.

Forest Service Personnel can easily incorporate this information into their management plan for the Lincoln National Forest. Conifer logs separated by a distance of about one m provide excellent ground cover. Logging practices should be modified, so that adequate-sized areas that meet these specifications are maintained.

Eggs, Juveniles and Adults

Juvenile salamanders were rarely collected, only 14 of the total 239 salamanders were juveniles. Johnston.and Schad (1959) also found adults to be more numerous than juveniles in their samples. Of the total juveniles, only three were not collected from logs. There were no distinct patterns between habitat characteristics and the presence of juveniles. They were located on steep (6 juveniles), moderate (7 juveniles) and gentle slopes (1 juvenile). Definitive data is not available to confirm if this low abundance of juveniles is characteristic for Aneides hardii. Juveniles may occur at other localities than adults and their activity patterns and behavior could be different. Or because of their smaller size, although juveniles are as numerous as adults, they may be more difficult to observe. Continued research is required on the natural history and ecology of this particular stage of salamander development, the juveniles.

Only one cluster of 6 eggs was sampled from the top contour on a steep slope (northeast aspect, 9000 ft elevation). These were found in a small cavity (about 3 in) of a decomposing conifer log. Since the sampling technique resulted in a disturbance of the eggs and an alteration of the deposition site, the eggs were placed in moist litter in an aquarium and

hatched in the laboratory. The eggs were examined under a microscope and all were viable. Five of the eggs (6-7 mm dia) hatched, 7 to 8 days after collecting. The gestation period for Aneides hardii eggs is unknown, but this information indicates it is at least 9 days, assuming laboratory conditions did not prolong this period. The newly emerged salamanders had snout-vent lengths of 11-13 mm (Total Length = 20-21 mm) and had color patterns similar to the adults. These were returned to an appropriate habitat shortly after hatching.

The number of eggs in this clutch was higher than that considered to be characteristic for the species. However, few clutches had been collected in earlier studies and little data exists on the variation in egg density per individual clutch. Additional information on individual and annual variation in the eggs per clutch and the frequency of egg deposition must be collected before the reproductive potential and fecundity of Aneides hardii can be assessed.

Major Taxa - Overstory, Midstory and Ground Story Cover

Table 7 provides a list of the major taxa comprising the vegetal cover. Differences do exist between transects with and without salamanders, regarding the frequency of occurrence of different taxa of plants. Acer and Picea were more frequently noted among overstory cover on transects with salamanders, whereas Pseudotsuga, Pinus, Quercus, and Robinia were located more commonly on transects without salamanders.

The taxa of midstory cover that were more likely to be encountered on transects without salamanders included Holodiscus, Quercus, Abies, Robinia, Populus, Sambucus and Symphoriocarpos. Jamesia and Acer were more typically found on transects with salamanders. Only minor differences in ground story

Table 7. List of major taxa comprising overstory, midstory and groundstory and their frequency of occurrence.

I. Taxa comprising overstory.

A. Localities without salamanders.

Pseudotsuga	91.5%	Quercus	29.8%
Abies	89.4%	Robinia	17.0%
Pinus	48.9%	Acer	17.0%
Populus	36.2%	Picea	0.04%

B. Localities with salamanders.

Abies	85.8%	Pinus	22.4%
Pseudotsuga	61.2%	Quercus	7.3%
Acer	50.8%	Robinia	4.5%
Populus	30.5%	Holodiscus	2.8%
Picea	28.0%	Others[1]	0.8-1.2%

[1] Others: Salix, Prunus and Jamesia

Table 7. (Continued)

II. Taxa comprising midstory.

A. Localities without salamanders.

Holodiscus	83.0%	Sambucus	14.9%
Quercus	36.2%	Symphoricarpos	8.5%
Ribes	23.4%	Pinus	8.5%
Abies	23.4%	Rubus	8.5%
Robinia	17.0%	Others[1]	1.0-4.3%
Populus	14.9%		

B. Localities with salamanders

Holodiscus	66.7%	Picea	8.1%
Ribes	26.8%	Quercus	7.7%
Jamesia	21.9%	Abies	7.3%
Acer	17.1%	Rubus	6.9%
Pinus	9.4%	Sambucus	6.1%
Actaea	8.5%	Populus	3.7%
Robinia	8.5%	Others[2]	0.8-3.2%

[1] Others: Actaea, Jamesia, Salix, Pseudotsuga, Acer

[2] Others: Pseudotsuga, Prunus, Salix, Rosa, Symphoricarpos

Table 7. (Continued)

III. Taxa comprising ground story.

A. Localities without salamanders.

Bromus	57.4%	Helenium	8.5%
Thalictrum	25.5%	Swertia	8.5%
Fragaria	25.5%	Muhlenbergia	8.5%
Geranium	21.3%	Medicago	8.5%
Poa	17.0%	Populus	8.5%
Galium	17.0%	Pterydium	8.5%
Smilecina	14.9%	Quercus	8.5%
Iris	10.6%	Others[1]	0.8-6.4%

B. Localities with salamanders.

Bromus	60.2%	Smilecina	8.5%
Fragaria	27.1%	Clovers	7.6%
Geranium	23.8%	Populus	7.6%
Poa	23.8%	Helenium	7.6%
Pterydium	17.8%	Galium	6.8%
Thalictrum	16.1%	Taraxacum	5.9%
Iris	13.6%	Muhlenbergia	5.9%
Parsley	10.2%	Sweet Cicily	5.1%
Rubus	9.3%	Others[2]	0.8-4.2%
Actaea	9.3%		

[1] Others: Actaea, Verbena, Abies, Aster, Stipa, Pinus, Dactylis, Acer, Agropyron, Holodiscus, Castilleja, Rubus, Sweet Cicily, Solidago.

[2] Others: Holodiscus, Achillea, Rhus, Robinia, Aster, Wormwood, Swertia, Quercus, Carex, Rosa, Symphoricarpos, Jamesia, Dactylis, Picea, Festica, Prunus, Abies, Sambucus, Koeleria, Lathyrusa, Cirsium.

taxa were recorded on the transects with and without salamanders.

This data on vegetation was categorized by using the classification method of Moir and Ludwig (1979) for spruce-fir and mixed conifer habitat types. It appears that salamanders were most frequently associated with the mixed conifer habitat type (HT) 14 (Abies concolor-Pseudotsuga menziesii/Acer glabrum). Lower densities of salamanders were also located in HT 16, Abies concolor-Pseudotsuga menziesii HT. The vegetation most commonly associated with those areas where salamanders were not found was categorized as HT 15, Abies concolor-Pseudotsuga menziesii/Quercus gambelii HT.

Nocturnal Sampling

Although a considerable portion of the field time was devoted to nocturnal sampling, this technique was very unproductive. Even after the sampling design was altered to include sampling by day along a different transect length (100 objects), few salamanders were located. Therefore, few conclusions can be made regarding the range of suitable salamander habitats occurring in the Sacramento Mountains. Only one salamander was collected from the 24 transects sampled nocturnally. Sixteen salamanders were located on seven of the thirty-five transects sampled diurnally. The range in habitat parameters on transects with salamanders was elevation (ft), 8900-9500; % slope, 10-33; % cover, 35-90 (canopy), 15-30 (midstory) and 10-90 (ground story) and D. B. H., 4-16 in.

Eight salamanders were collected from slopes with a southwest aspect (220-240^{o}), five from slopes with a northwest aspect (290^{o}) and one salamander, respectively, from slopes with west (270^{o}), northeast (60^{o}) and

north (0^{o}) aspects. To generally assess the overall importance of aspect, this information was combined with the data for individual salamander sites. Of the total salamanders collected (239), 7 salamanders were located on slopes of northwest aspect ($270-350^{o}$), 12 from southwest ($170-290^{o}$), 9 from east (90^{o}), 4 from north (0^{o}), one from southeast (130^{o}) and all the rest were from slopes with northeast aspects ($10-80^{o}$). Apparently salamanders do inhabit more mesic areas of the Sacramento Mountains, however, data do not allow estimates of salamander density in the different types of habitat.

Distributions of Salamander Populations

A map depicting the locations of all sample transects and the proposed distribution of optimum habitat in the Cloudcroft and Mayhill Ranger Districts of the Lincoln National Forest for Aneides hardii populations is included with this report.

LITERATURE CITED

Johnson, R. F. and G. A. Schad. 1959. Natural history of the salamander, Aneides hardii. Univ. Kansas Publ. Mus. Nat. Hist. 10:573-585.

Lowe, C. H., Jr. 1950. The systematic status of the salamander, Plethodon hardii, with a discussion of the giogeographical problems in Aneides. Copeia, 1950:92-99.

Moir, W. H. and J. A. Ludwig. 1979. A classification of spruce fir and mixed conifer habitat types of Arizona and New Mexico. U.S.D.A. For. Serv. Res. Pap. RM-207, 47 p. Rocky Mt. For. and Range Exp. Stn., Ft. Collins, Colo.

Ray, C. 1958. Vital limits and rates of dessication in salamanders. Ecology 39:75-83.

Rosenthal, G. M. 1957. The role of moisture and temperature in the local distribution of the plethodontid salamander, Aneides lugubris. Univ. Calif. Pub. Zool. 54:371-420.

Wake, D. W. 1965. Aneides hardii. In: W. J. Riemer (ed), Catalogue of American Amphibians and Reptiles. American Society of Icthyologists and Herpetologists, Kensington, Maryland. p. 17.

Whitford, W. G. 1968. Physiological responses to temperature and dessication in the endemic New Mexico plethodontids, Plethodon neomexicanus and Aneides hardii. Copeia, 1968:247-251.

KEY:

TRANSECTS WITH SALAMANDERS

TRANSECTS WITHOUT SALAMANDERS

OPTIMUM SALAMANDER HABITAT (≥ 8800 FT, ELEVATION)